NOSIA-II Calibration using Sensitivity Studies

A novel method for extending OSE/OSSE impacts through the NOAA Value Tree

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Poster Abstract

Observing system experiments (OSEs) are important in determining the impact of various earth observing systems on a numerical weather prediction (NWP) model. Observing system simulation experiments (OSSEs) are critical in examining future observing system impacts or changes in configuration on an NWP system. While an OSE or OSSE provides a quantitative analysis of current or future observing system impacts for a single model, the effects on products that rely on that model can only be estimated qualitatively. Additionally, the observational impacts due to observing system configuration changes cannot be gauged concurrently across a suite of NWP models (such as those at the NCEP Environmental Modeling Center).

The NOAA Observing System Integrated Analysis (NOSIA-II) study surveyed subject matter experts (SMEs) across all NOAA Line Offices to gauge the impacts of the current Earth observation portfolio on the key products and services that define NOAA's core missions via interviews with subject matter experts. The Technology, Planning, and Integration for Observation (TPIO) Office and the Joint Center for Satellite Data Assimilation (JCSDA) have collaborated on a pioneering prototype calibration of NOSIA-II results for GFS with an OSE study conducted by JCSDA on the impact of losing JPSS in the afternoon orbit. Preliminary results will be shown on this poster.

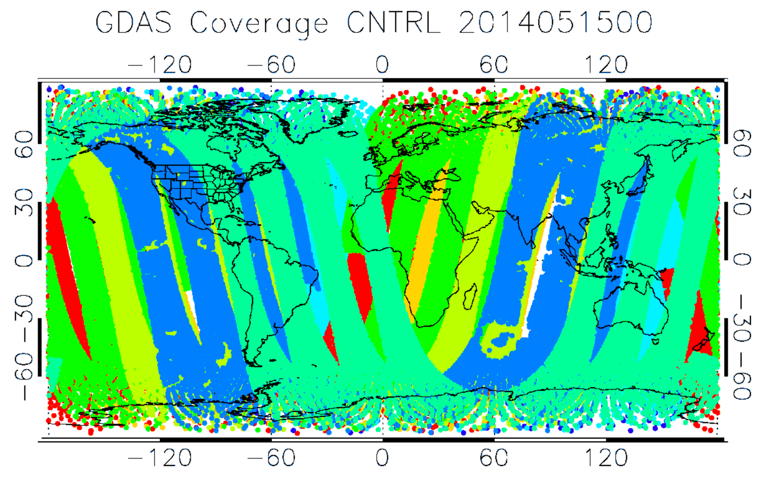
Background Information on JPSS PM orbit study

JPSS PM orbit study recently completed by JCSDA looked at 3 potential future possibilities:

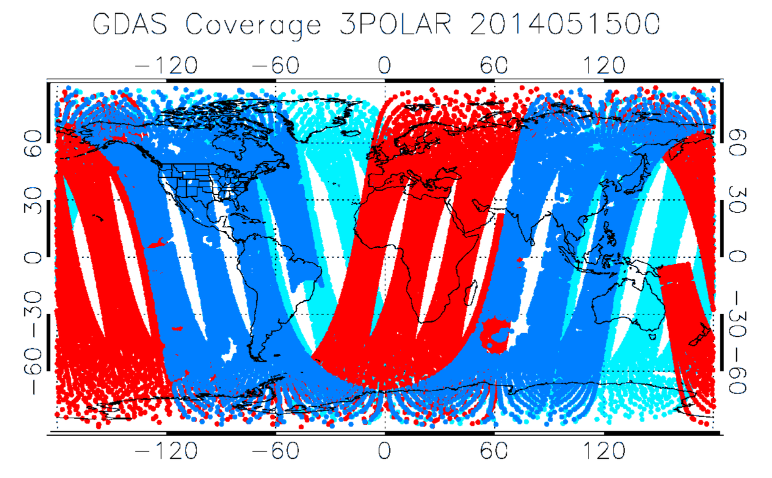
- 3 polar satellites only. Includes JPSS and all other available satellite data (GPSRO, Geo, etc) → 3POLAR experiment
- 2 polar satellites only (no JPSS); all other data available → 2POLAR experiment
- 3 polar satellites only + tropics-only GPSRO → 3PGPS (analysis not shown for this case).

JCSDA utilized several bulk metrics to assess impact of losing polar satellite:

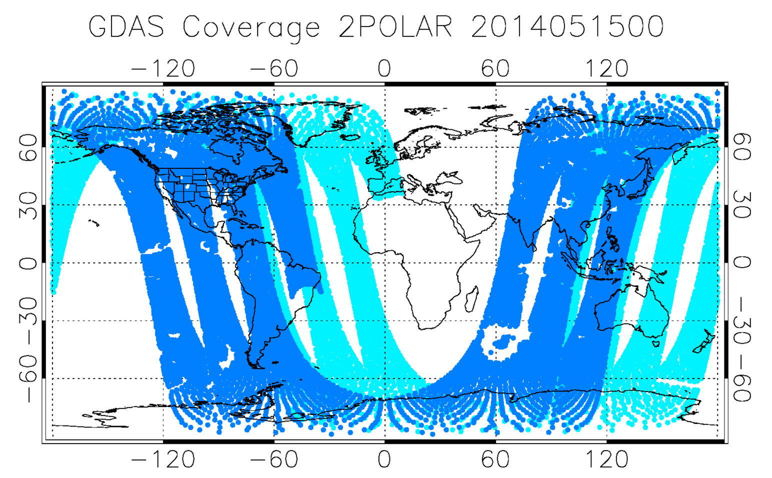
- We worked with the Cumulative Forecast Score (CFS).
- CFS takes into account the Root Mean Squared Error (RMSE) and Anomaly Correlation metrics
- RMSE and AC values summed up for 4 height levels, 7 forecast times, and 3 environmental parameters.



Polar Orbiter coverage for GFS Control Run



Polar Orbiter coverage for GFS 3Polar case



Polar Orbiter coverage for GFS 2Polar case

Cumulative Forecast Score (CFS) Equation

From "Assessing the Impact of a Degraded Satellites Constellation on NOAA NWP" (Boukabara et. al. 2015)

CFS = $\alpha C_{AC} + \beta C_{RMSE}$, where CFS is weighted average between Cumulative Anomaly Correlation (**C_{AC}**) score and Cumulative Root Mean Square Error (**C_{RMSE}**) score:

$$C_{AC} = \sum_{i=1}^{np}\sum_{j=1}^{nlev}\sum_{k=1}^{nhr}\left(\frac{ac_{i,j,k}-\min_k}{\max_k-\min_k}\right)$$

$$C_{RMSE} = \sum_{i=1}^{np}\sum_{j=1}^{nlev}\sum_{k=1}^{nhr}\left(1-\left[\frac{rmse_{i,j,k}-\min_k}{\max_k-\min_k}\right]\right)$$

Where α and β = 0.5, and:

np = 3 parameters (Geopotential Height, Temperature, Vector Wind)

nlev = 4 levels (250 mb, 500 mb, 700 mb, 850 mb)

nhr = 7 forecast hours (24-hr, 48-hr, 72-hr, 96-hr, 120-hr, 144-hr, 168-hr)

max_k = maximum score at forecast time k

min_k = minimum score at forecast time k

Why is this important?

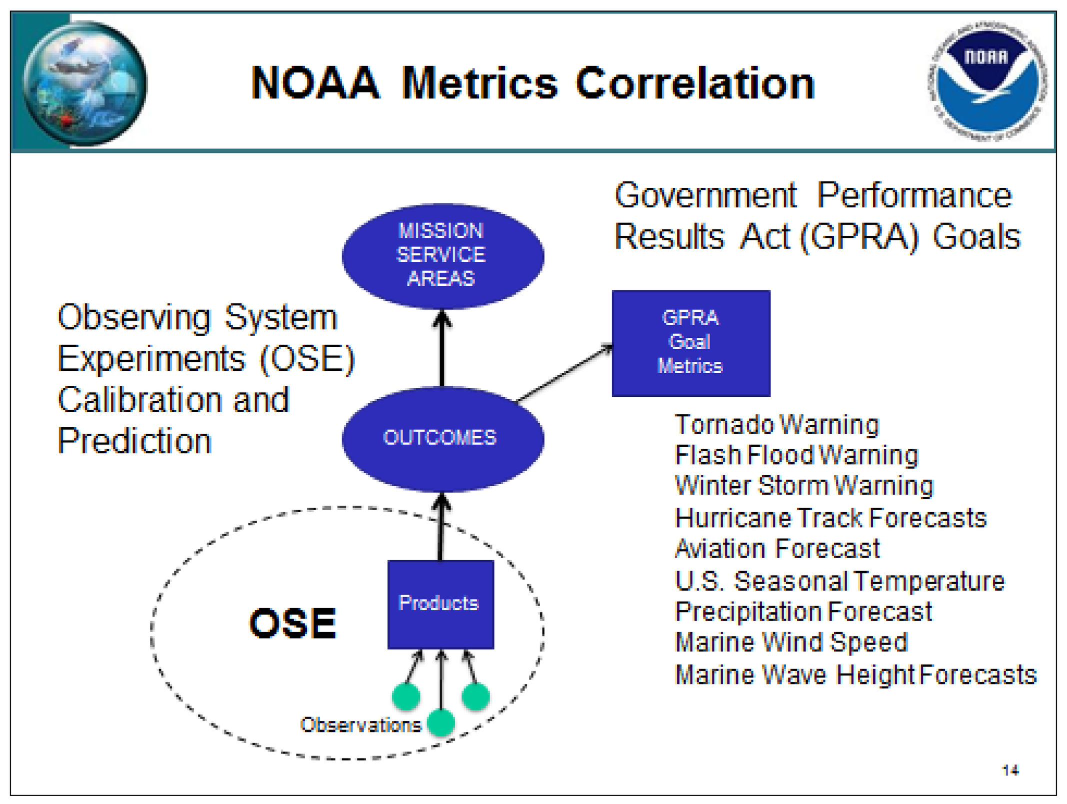
In general, an OSE (such as the JPSS PM orbit study) or OSSE provides observing system impacts in a mathematical, physically-based representation of the atmosphere (such as the GFS). But how can we translate those impacts on NOAA 's suite of products and services that depend on GFS?

Answer: NOSIA!!

NOSIA is a complex model of NOAA's business practices used to affect outcomes

- Decision support tool for value-tree based analysis
- 72 survey sites, >1,100 surveyed products, >500 SME elicitations
- 565 unique data sources each influencing up to 370 products
- Sometimes as many as 80 data sources for a product
- Line Offices provided Product priorities and linkage to outcomes
- GFS was noted as a data input in 349 surveyed products!

NOSIA-II Performance (Satisfaction) Scale		
100	Ideal	Meets all requirements and exceeds some
90	Fully Satisfied	Meets all requirements
80	Good	Meets all major requirements, with minor limitations
60	Fair	Meets most major requirements, with significant limitations
40	Poor	Fails to meet many major requirements, but provides some value
20	Very Poor	Fails to meet most major requirements, but provides minor value
1	No Capability	Provides no value



Calibration of NOSIA-II with OSE results not only allows us to "flow the impacts up to higher value tree levels, it also allows standardization of NOSIA impact results with GPRA goals and other performance metrics

Methodology

$$SQ'_{CNTRL} = \underbrace{w_1\lambda C_{CNTRL}}_{\text{Component of GFS requirements examined by OSE}} + \underbrace{(1-w_1)x}_{\text{Component of GFS requirements not examined by OSE}}$$

λ = Rescaling factor that depends on C_{CNTRL}, w_1, and SQ'_{CNTRL}

w_1 = Weight of OSE component

$1-w_1$ = Weight of non-OSE component

C_{CNTRL} = Baseline Cumulative Forecast Score (CFS) for current architecture setup for control run

SQ'_{CNTRL} = Baseline Status Quo Score for current architecture setup (85 for current GFS)

Example: Let's assume OSE addressed 75% of requirements for GFS.

- Then, w_1 = 0.75 and $1-w_1$ = 0.25.
- Let's also set x = 85 to show performance of GFS component not examined by OSE is equal to baseline status quo score.
- Finally, for the JPSS PM orbit study, C_{CNTRL} = 0.697.
- Using values as defined above, λ = 121.95122

Converting CFS scores from JPSS PM Orbit Study to equivalent SQ scores

We can plug the CFS values from each experiment into the following general equation: $SQ_E = w_1\lambda C_E + (1-w_1)x$, where E = 3POLAR, 3PGPS, or 2POLAR Experiment.

- C_{3POLAR} = CFS score for 3 polar satellites only. Includes JPSS and all other available satellite data (GPSRO, Geo, etc) = **0.566**
- C_{3PGPS} = CFS score for 3 polar satellites only + tropics-only GPSRO. Includes JPSS and all other available data = **0.501**
- C_{2POLAR} = CFS score for 2 polar satellites only (no JPSS); all other data available = **0.463**
- EMC noted that losing Microwave/IR radiances and GPSRO degrade GFS SQ score by 69.4% in NOSIA-II; hence w_1 = **0.694**

Using the known values of w_1 = 0.694, λ = 122.95122, $1-w_1$ =0.306, and x =85, we plug in the CFS scores from above to derive the corresponding SQ score for each experiment:

SQ_{3POLAR} = [(0.694)(121.95122)(0.566)] + [0.306(85)] = **73.91**

SQ_{3PGPS} = [(0.694)(121.95122)(0.501)] + [0.306(85)] = **68.41**

SQ_{2POLAR} = [(0.694)(121.95122)(0.463)] + [0.306(85)] = **65.20**

		CNTL	3POLAR	3POLAR-CNTL	2POLAR	2POLAR-CNTL
Top Node	NOAA	66.01933	66.01153	-0.0078	66.00538	-0.0139
Goal	Climate Adaptation and Mitigation	68.54256	68.52739	-0.0152	68.51551	-0.0271
Goal	Healthy Oceans	52.42053	52.41216	-0.0084	52.40539	-0.0151
Goal	Resilent Coastal Communities and Economies	69.47888	69.4789	0.0000	69.47896	0.0001
Goal	Weather Ready Nation	73.63533	73.62765	-0.0077	73.62167	-0.0137
MSA	Aviation Weather and Volcanic Ash	73.32094	73.32111	0.0002	73.3212	0.0003
MSA	Fire Weather	75.95175	75.95067	-0.0011	75.9504	-0.0014
MSA	Hurricane/ Tropical Storms	66.7529	66.75302	0.0001	66.75313	0.0002
MSA	Hydrology and Water Resources (Integrated Water Forecasting)	72.95139	72.94761	-0.0038	72.94554	-0.0059
MSA	Marine Weather and Coastal Events	73.62925	73.55268	-0.0766	73.49092	-0.1383
MSA	Routine Weather	80.01527	80.01459	-0.0007	80.01435	-0.0009
MSA	Severe Thunderstorms, Tornados and Flash Floods	75.46817	75.46767	-0.0005	75.46755	-0.0006
MSA	Weather Ready Nation Science, Services, and Stewardship Advanced	57.94438	57.94304	-0.0013	57.94194	-0.0024
MSA	Winter Weather	80.75723	80.75636	-0.0009	80.75593	-0.0013
MSA	*Environmental Modeling Prediction*	68.67858	68.32776	-0.3508	68.04904	-0.6295

Results Summary and Future Work

- Slight degradation shown for 3 of the 4 goals, and 8 WRN MSAs if 3Polar and 2Polar scenarios come to pass.
- Largest Impact by far of a degraded GFS is on the Environmental Modeling Prediction MSA.
- Conservative estimate of degradation, due to the fact we didn't include direct impact on other products of losing the polar orbiters, in order to isolate effects from have degraded GFS as an input.
- Suggests there is merit in this methodology, but will need to determine significance of degradation amount.
- Will also continue working with EMC NWP/ocean modelers to fine-tune calibration method.

Other NOSIA-II talks at 96th AMS Annual Meeting:

Formal Poster Viewing
1/11/2016 2:30 - 4:00 PM and 1/12/2016 9:45 - 11:00 AM
NOAA Observing System Integrated Analysis (NOSIA-II) Integration with the Broader Federal Earth Observation Assessment Effort

Presentations
1/13/2016 9:30 - 9:45 AM
Applications of the Earth Observation Requirements Evaluation System

1/14/2016 8:30 - 8:45 AM
The Continued Evolution of NOAA's Observing System Investment Assessment Process